Report for 2004IA62B: Identification of Relationships Between Soil Phosphorus and Phosphorus Loss Through Tile Drainage to Improve the Subsurface Drainage Component of the Iowa Phosphorus Index.

Publications

- There are no reported publications resulting from this project.

Report Follows

Identification of Relationships Between Soil Phosphorus and Phosphorus Loss through Tile Drainage to Improve the Subsurface Drainage Component of the Iowa Phosphorus Index

Antonio P. Mallarino, Rameshwar S. Kanwar, Matt J. Helmers

Problem and Research Objectives

This project is at the end of its second and last year. The problem addressed by the study and objectives were explained in the original proposal, did not change during its two years, and only a brief summary is included here.

Many questions related to the impact of current P management practices on P-related water quality are being asked by the public, government agencies in charge of nutrient regulations, producers, and researchers. Excess P often is delivered from agricultural fields to water resources because of inappropriate fertilizer or manure management or the need to dispose of manure at a low cost. Management guidelines and regulations are being established based on a P risk assessment tool often referred to as the P index. Although a P index has been developed for Iowa and many other states, gaps and insufficient information about some processes have created a great deal of uncertainty for some P index components. This project focuses on excess dissolved P loss through subsurface drainage that can occur when soil P concentration increases. Although many studies have monitored P concentration in tile drainage, few (and none in Iowa) have studied relationships between soil-test P and P loss through tiles. Soil-test P is affected by P fertilization, manure application, crop production, and several management practices. Although results of agronomic soil P tests are currently used in P indices, environmental P tests have been proposed as an alternative to these to measure P in soil and runoff water. There is little information concerning correlations of P extracted by either agronomic or routine tests and P loss through subsurface drainage. Limited information led the team that developed the Iowa P index to include approximate estimates of relationships between soil-test P and P loss in its subsurface drainage component.

The overall goal of the project is to establish relationships between soil P measured by various tests, fertilizer and manure P management, and P loss through subsurface drainage. The work is an interdisciplinary effort that uses existing facilities and inter-departmental cooperation to achieve objectives at a low cost. Specific objectives are:

1. Study the impact of fertilizer and manure applications on soil P measured with routine agronomic soil tests and environmental soil test methods that emphasize an assessment of potential P losses to water supplies.
2. Establish relationships between soil-test values and P concentrations in subsurface tile drainage for selected manure/fertilizer management systems.
3. Develop equations that can be included in future revisions of the soil P factor of the subsurface drainage component of the Iowa P index.

Methodology

The methods used in the study follow those planned and explained in detail by the original proposal. Briefly, soil and tile drainage samples are collected from plots of three long-term field experiments that include replicated manure application treatments or a combination of nutrient and cropping systems treatments. All plots have a tile drainage collection system with automatic water sampling devices. One experiment at the Northeast Research Farm (near Nashua) evaluates six cropping (tilled or no-till) and liquid swine manure/fertilizer management systems for corn-soybean rotations managed with chisel-plow tillage except for one system. The systems compare N and P fertilization according to crop needs (two systems varying only in N fertilizer application method), manure according to the N needs of the corn (in two systems, one with manure applied in spring for no-till and one with manure applied in the fall for chisel-plow tillage) and supplemental P fertilization as needed for soybean, manure according to the P needs of the corn plus supplemental N as needed to apply the same total N rate as the previous treatments, and manure according to the N need of corn and estimated N removal by soybean. The manure is always injected. Two other experiments are conducted at the Agronomy and Agricultural Engineering Research Farm (near Ames). One experiment includes three rates of poultry manure (egg layers) compared with equivalent N fertilizer rates for the corn in corn-soybean rotations managed with chisel-plow tillage. The other experiment evaluates injected liquid swine manure at three rates for corn in corn soybean rotations managed with chisel-plow tillage and broadcast liquid swine manure at one rate for continuous corn also managed with chisel-plow tillage. The total manure-N applied for corn in these two experiments ranges from 100 to 300 lb N/acre, which encompasses the range of 100 to 150 lb N/acre recommended for corn after soybean in Iowa, and at the same time applies manure P at approximately 70 to 250% of the P maintenance rate recommended for the 2-year corn-soybean rotation.

Principal Findings and Significance

Treatment Effects on Soil P

Soil samples were collected from a depth of 0 to 6 inches as planned and their chemical analyses have been completed. All deep soil samples planned in the original proposal could not be collected as a result of a significant budget reduction, although samples were collected in 2004 from plots of two trials. Considering soil samples collected in 2003 that were analyzed for the project and those collected in 2004 and 2005, more than 600 soil samples were analyzed for P and pH. The preliminary results of the soil analyses are summarized in the following points.

1. The treatments applied to these experiments resulted in large differences in soil-test P values for the 6-inch top layer of soil. The results of routine soil P tests (Bray-1, Mehlich-3, and Olsen) indicated that soil-test P remained near optimum for corn and soybean production in plots that received fertilizer or manure P at rates that applied P near the rates suggested by current P management guidelines in Iowa to maintain soil-test P. The optimum soil-test interpretation class for corn and soybean ranges from 16 to 20 ppm by Bray and Mehlich-3 tests and 11 to 14

ppm by the Olsen test, all with a colorimetric determination of extracted P. Soil-test P was lower in plots receiving lower P application rates, although no treatment resulted in soil-test P in the Very Low class. However, manure rates that applied two to three times the N required by corn or the N required by corn plus N removed by soybean significantly increased soil-test P values to values as high as six times the Optimum class (up to 140 ppm by the Bray-1 or Mehlich-3 tests and higher than 80 ppm by the Olsen test). Obviously, this soil P build-up was the result of P applications since the experiments were established in the late 1990s and not exclusively from P applied during the duration of this project.

2. Manure of fertilizer P application at rates that maintained soil-test P near optimum values for crops did not affect soil P concentration at depths deeper than 6 inches as measured in two experiments. Higher manure P rates increased only slightly P concentrations in the 6- to 12-inch layer of soil but did not significantly change subsoil P concentrations to a depth of 12 to 36 inches. The finding that high P applications did not increase subsoil P below a depth of 12 inches strongly suggests that although some P movement down the profile may have existed (as tile P concentrations indicate as discussed below), it was small and not detectable over a period of a few years. Furthermore, the small P increase in the 6–12 inches layer seldom was statistically significant and was observed only for plots that received the highest manure P rates, such as manure for corn at rates two to three times its N requirement or when manure also was for soybean at N-removal rates.

3. Chemical analyses of samples and study correlations between soil P measured by agronomic and environmental tests (soil bioavailable P or water-extractable P) are not completed, but the available data indicate high correlation between all P tests. Although, as expected and is known, the amounts of measured soil P varied greatly among P tests, all tests detected the effects of P applications similarly and were highly correlated. Because these results were observed across long-term plots receiving fertilizer P, swine manure, and poultry manure we also conclude that all these tests evaluate similarly effects of these P sources on soil P accumulation.

Relationships BetweenTile Drainage P and Treatments or Soil P Concentrations

Data on P concentration of tile drainage are available for the years 2003 and 2004. Although tile drainage was also sampled as planned from all experiments and plots in 2005, the samples were not analyzed yet. Collaborators of the Department of Agriculture and Biosystems Engineering collected these samples and were planning to analyze them with support from other funding sources. Unfortunately, funding was short due to significant budget cuts and the pace of water sample analysis was slowed significantly. Moreover, analyses of samples collected in 2004 from one site were completed only recently and results have not been carefully studied for possible outliers are available at this time. However, the data available for other years allow for the following preliminary conclusions at this time.

1. Weighted-average orthophosphate P concentration in tile water ranged from values less than 10 ppb (parts per billion) to 220 ppb, although values seldom were higher than 100 ppb. The highest value corresponded to some plots of treatments in which manure was applied every year to both corn and soybean or only for corn at rates that applied amounts twice or higher than the N needed. The lowest values corresponded to treatments in which either fertilizer or manure P was applied at rates similar to or lower than those needed to maintain soil-test P for the 2-year corn-soybean rotation according to current recommendations in Iowa. Interestingly, P concentrations and loads in tile drainage also were very low, most of the time not significantly different from the P-based treatments, when swine or poultry manure was applied only for corn at N-based rates or even about 50% higher. These results match results of soil P tests in that swine manure application at rates that supply N needs of corn approximately supply the P needs of the two crops of the rotation and do not result in large soil P build-up or elevated P concentrations in tile drainage. Application of N-based poultry manure for corn did result in soil P build-up but not significantly higher tile P concentrations compared with lower rates. Calculations of annual P loads even for the treatments that resulted in the highest P concentrations in tile drainage (such as manure applied every year to both crops or only for corn at rates that applied amounts twice or higher than the N needed) indicated very low P loss, less than 0.1 lb P/acre/year.

2. Available relationships between P concentrations in tile drainage or P loads and soil P measured by various methods across sites and years indicate very low P loss (< 20 ppb) up to soil-test P levels five to six times as large as levels required by crops. At higher soil-test P levels the P concentrations in tile drainage were very variable ranging from the lowest values observed at the lowest soil-test P levels up to the highest values observed in the study and there was no clear relationship between the two measurements. These results coincide with results observed in previous years in Iowa. We hoped that continued application of swine manure rates higher than N-based rates for corn and N-based or higher poultry manure rates would result in a faster soil P build-up and increased P concentration in tile drainage. Perhaps the results for samples collected in 2005 will show this effect. The results available at this time do indicate, however, that very high soil P concentrations, higher than levels measured in these experiments, are needed in Iowa soils to increase P loss in tile drainage to levels significantly or consistently higher than the low background levels observed at low soil P levels or those required for optimum crop production.

Implications of Results for the Subsurface Drainage Component of the Iowa P Index

The preliminary results have significant implications for the subsurface component of the Iowa P Index. One important implication is that the relationships between P concentrations in soil and tile drainage did not suggest a change to the current two-class factor of the component (for Bray soil P, for example, the factor indicates low or high P loss at and below or above a threshold value of 100 ppm). We hoped that increased soil P build-up in these trials would result in higher P concentration and loss in tile drainage and

would allow for fitting either an exponential or grafted polynomial (discontinue) regression model including a near-plateau at low soil P levels and an increasing linear trend at higher concentrations. This type of relationship sometimes has been identified by research in other states at much higher soil P levels and significantly different soil types. The available results indicated that much, much higher soil P levels (probably higher than 200 to 300 ppm by the Bray-1 method) might be needed to observe significantly high P loss through tile drainage and clear exponential or linear increases in P loss as soil P concentration increases.

Another important preliminary result of this study is a confirmation that P losses through tile drainage are much, much smaller than P loss through surface runoff or soil erosion, which is recognized and accounted for the by the Iowa P Index. Unless soil P is extremely high, much higher than about 150 ppm by the Bray soil test, for example, efforts at reducing P loss from Iowa fields will be more effective by focusing on management practices affecting P loss with runoff and soil erosion.

No articles or publications have been prepared because only partial and preliminary results are available at this time. However, the project and results have been presented and discussed at six field days or indoor meetings during the last two years, an annual meeting of the American Society of Agronomy, a P conference with Iowa and Illinois technical personnel of NRCS and state agencies, a meeting of the Iowa Nutrient Task Force, and a meeting of the Environmental Protection Commission of the Iowa legislature.